

# ***DOE Office of Electricity Energy Storage Development at PNNL***

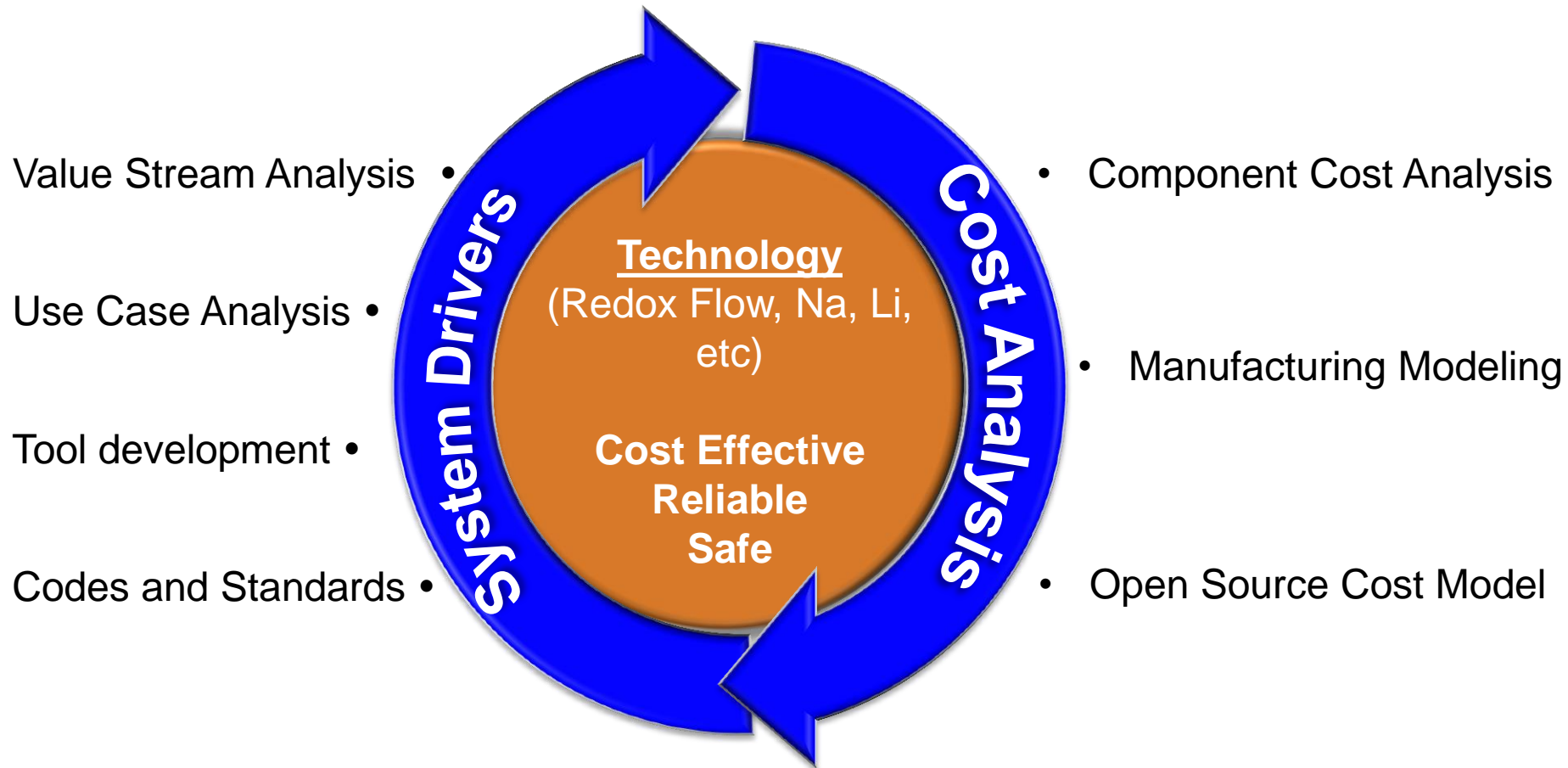
**Vincent Sprenkle**, Wei Wang, David Reed, Michael Kintner-Meyer, Jin Yong Kim, Xioalin Li, Daiwon Choi, David Conover, Vish Vishwanathan, Patrick Balducci, Ed Thomsen, Guosheng Li, Xiaochuan Lu, Bin Li, Xiaoliang Wei, Zimin Nie, Brent Kirby, Vijay Murugesan, Kerry Meinhardt, Brian Koeppel, Di Wu, Leo Liu, Lelia Cosimbescu, Scott Whalen, Landis Kannberg

## **Pacific Northwest National Laboratory**

DOE Office of Electricity Energy Storage Program – Imre Gyuk Program Manager.

OE Energy Storage Systems Program Review  
September 17<sup>th</sup>, 2014

# Stationary Energy Storage Development Approach



# Stationary Energy Storage Analysis

## **Primus/PSE/BPA Analysis**

P. Balducci: 8/19 - 3:30 pm



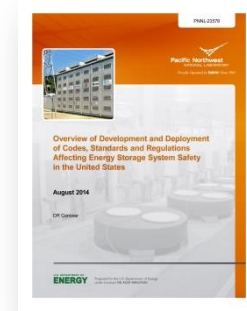
## **Powin/BPA Demonstration**

V. Vishwanathan:  
8/19 - 11:35 am



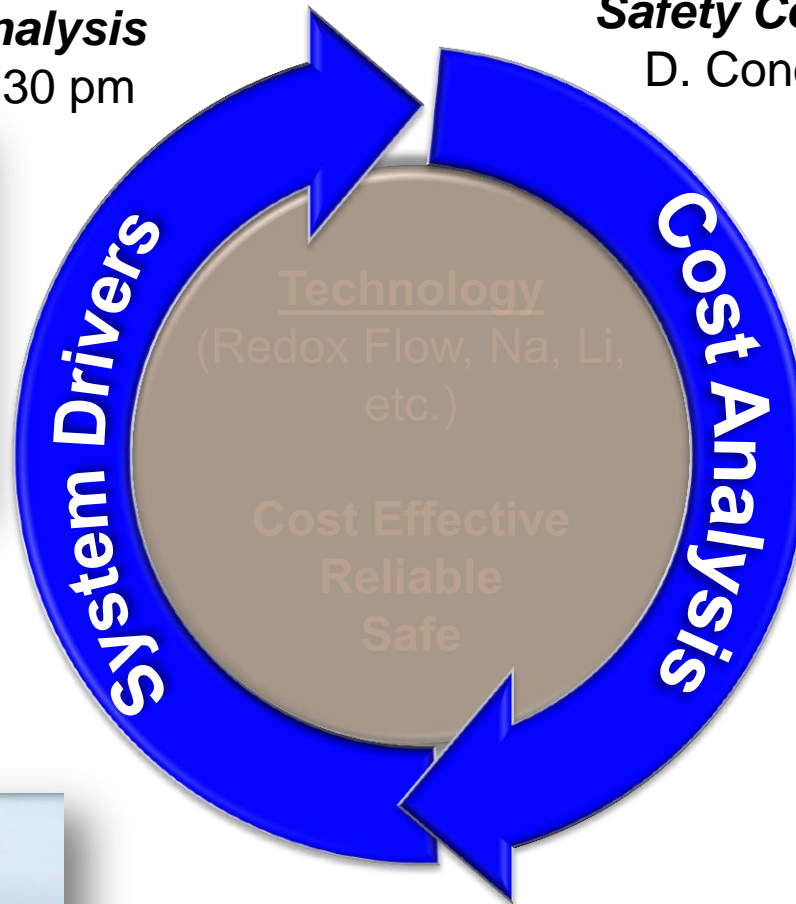
## **Safety Codes and Standards**

D. Conover: 8/19 8:55 am



## **WA State Use Case Development**

L. Kannberg: 8/19 11:55 am



## **International Energy Storage Working Group**

V. Vishwanathan: 8/18 Poster

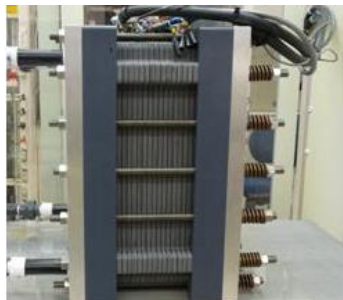
## **Manufacturing Cost Model RFB**

S. Whalen: 8/17 Poster

# Stationary Energy Storage Technology

## V/V Flow Battery Stack

D. Reed: 8/17 – 9:55 am

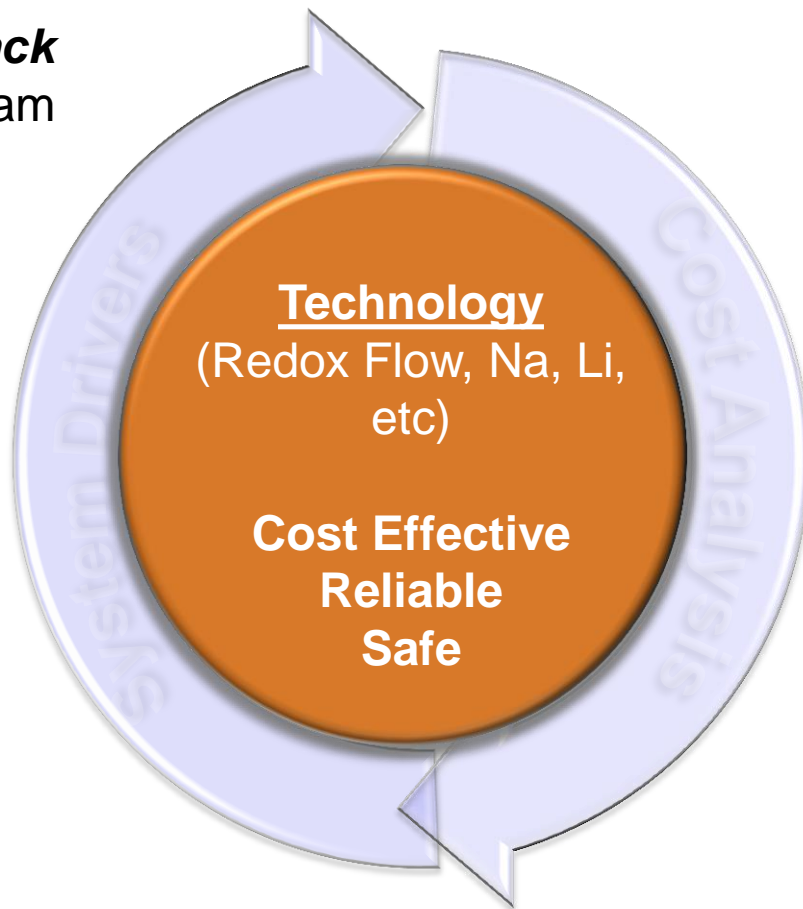
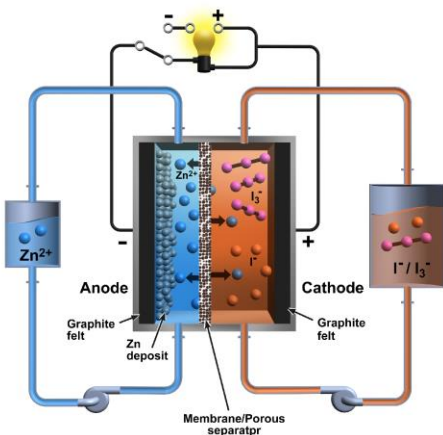


## Advanced Flow Batteries

W. Wang:

8/17 – 11:15 am

8/17 – 12:50 am



## RFB Membrane Development

X Wei: 8/17 Poster

## Catalyst Development VRFB

B. Li: 8/17 Poster

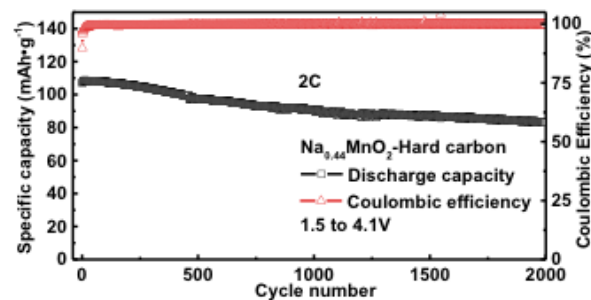
## IT Na-metal Halide

JY Kim: 8/18 – 8:25 am



## Na-ion Batteries

X. Li: 8/17 – 2:10 pm





# FY14 Accomplishments

## ▶ 3 patents issued including V/V and V/Fe mixed acid system

- “Redox flow batteries based on supporting solutions containing chloride” US 8,628,880, Issued: Jan 14, 2014
- “Fe-V redox flow batteries” US 8,771,856, Issued: Jul 8, 2014
- “Methods and apparatuses for making cathodes for high-temperature, rechargeable batteries” US 8,728,174, Issued: May 20, 2014

## ▶ 5 patent applications

- “Polymer sealing technology for planar ZEBRA batteries (190°C)” 14/464,356, Filed: Aug 20, 2014.
- “Novel Na-FeCl<sub>2</sub> Zebra battery”: 14/464,356, Filed: Aug 20, 2014.
- “Simultaneous conversion and sintering of beta-alumina” 14/465,476, Filed: Aug 18, 2014.
- “Non-aqueous metal-iodine redox flow battery” 14/294,391, Filed: Jun 6, 2014.
- “Hybrid anode for lithium based non-aqueous redox flow battery” 14/166,389. Filed: Jan 28, 2014.

## ▶ 1 license agreement (Technology)

- Aartha US: Fe-V redox mixed acid electrolyte.

## ▶ 5 license agreements (Tools)

- Royalty free license “Battery Storage Evaluation Tool”

# FY14 Accomplishments

## ► 8 peer reviewed publications

- X. Lu, et al, "Liquid-metal electrode to enable ultra-low temperature sodium–beta alumina batteries for renewable energy storage." **Nat. Commun.** 5:4578 doi: 10.1038/ncomms5578 (Aug 2014).
- Yingwen Chenget, et al, "High performance batteries based on hybrid magnesium and lithium chemistry" **Chem. Commun.**, 2014, 50, 9644-9646 (July 2013)
- Ran Yi, et al, "GeOx/Reduced Graphene Oxide Composite as an Anode for Li-ion Batteries: Enhanced Capacity via Reversible Utilization of Li<sub>2</sub>O along with Improved Rate Performance", **Advanced Functional Materials**, 24, p.1059-1066 (Feb 2014).
- Viswanathan VV, et al, "Cost and Performance Model for Redox Flow Batteries." **Journal of Power Sources** 247:1040-1051. doi:10.1016/j.jpowsour.2012.12.023 (Feb 2014)
- G, Li, et al, "Improved cycling behavior of ZEBRA battery operated at intermediate temperature of 175°C," **Journal of Power Sources** 249 (2014) 414-417 (Jan. 2014)
- B Li, et al, "Nanorod Niobium Oxide as Powerful Catalysts for an All Vanadium Redox Flow Battery", **Nano Letterers**, 2014, 14, 158-165. (Dec 2013)
- G. Li, et al, "Cell Degradation of a Na-NiCl<sub>2</sub> (ZEBRA) Battery," **Journal of Materials Chemistry A**, 47 (2013) 14935 – 14942 (Nov 2013)
- B Li, et al, "On-Line Investigation of the Capacity-Decay Mechanism of Micro-porous Separator-Based All-Vanadium Redox Flow Batteries and Its Recovery", . " **ChemSusChem**, 2014, 7, 577 – 584. (Oct 2013)

## ► 4 Reports

- P. Balducci, et al "Assessment of Energy Storage Alternatives in the Puget Sound Energy System Volume 1: Financial Feasibility Analysis" PNNL- 23040
- P. Balducci, et al "Assessment of Energy Storage Alternatives in the Puget Sound Energy System Volume 2: Energy Storage Evaluation Tool" PNNL-23039
- DR Conover "Inventory of Safety-related Codes and Standards for Energy Storage Systems" PNNL-23618.
- DR Conover "Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States" PNNL-23578

# Acknowledgements

- US DOE Office of Electricity – Dr. Imre Gyuk, Energy Storage Program Manager
- Stationary Energy Storage Team at PNNL:  
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